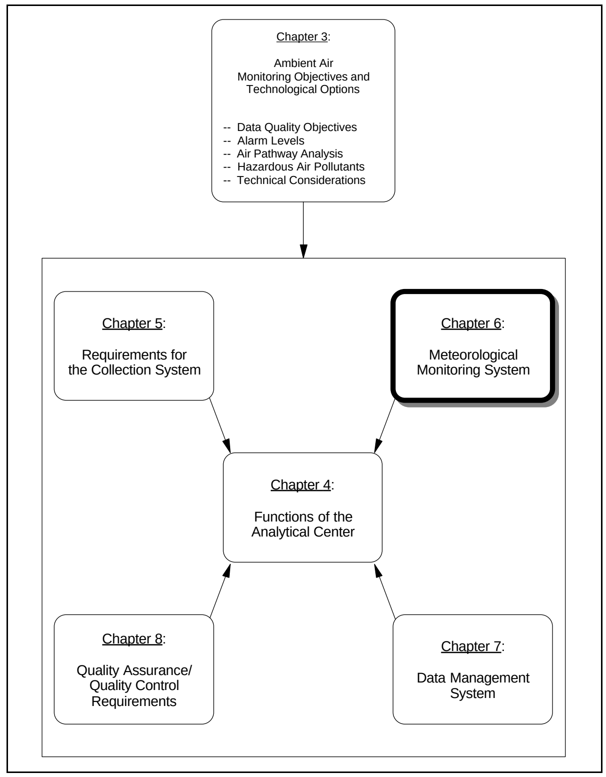
SUMMARY OF METEOROLOGICAL MONITORING SYSTEM

The meteorological system is an outreach of the analytical center and an integral component of any perimeter air monitoring program. This system collects meteorological data that is recorded and stored in the analytical center.



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- Purpose of Meteorological System

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- Meteorological Data Collection and Parameters
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The Meteorological System assists with determining the risk assessment to off-site receptors from contaminants leveling the site during remediation. Chapter 6 discusses the integration of the meteorological data with the perimeter air monitoring program. Users will be introduced to the meteorological parameters to be monitored, siting criteria and tower requirements, the communication process of the meteorological station with the analytical center, QA/QC, and data processing at the analytical center.

Panel 6-1. Overview of the Meteorological Monitoring System.

6-1. Introduction

Meteorological monitoring assists with determining the net site emissions and risk to off-site receptors from contaminants leaving the HTRW site during remediation. Meteorological monitoring coupled with pollutant monitoring allows an assessment of the air pathway during all times that air quality data is collected. In particular, most models used in determining emission rates of pollutants from a HTRW site require the input of wind speed, wind direction, temperature, precipitation, relative humidity, barometric pressure, and atmospheric stability.

The same QA/QC activities associated with FFMS pollutant monitoring must be implemented in the meteorological monitoring program. The monitoring of atmospheric conditions must be (1) representative of the atmospheric conditions that affect the pollutant being transported off the site, (2) comparable across the measurement network, and (3) of the same quality as the pollutant measurement program.

The objective of Chapter 6, Meteorological Monitoring System, is to discuss the integration of the meteorological data with the FFMS. This chapter will discuss the meteorological parameters to be monitored, siting criteria and tower requirements, communication of the meteorological station with the Analytical Center, QA/QC, and the processing of meteorological data for input to site-specific models.

Meteorological sensors must provide data of sufficient accuracy and resolution to enable a meaningful interpretation of the monitoring results.

6-2. Meteorological Monitoring System and Organization

a. Introduction. The purpose of this paragraph is to provide detailed information on meteorological monitoring stations that could be used to obtain continuous on-site meteorological data at an HTRW site. Included are an introduction that addresses the necessity for meteorological monitoring; a section on meteorological data collection parameters that discusses siting a station, tower requirements, and the parameters that need to be measured; descriptions of alternative communication processes, data and reporting formats, data QA/QC, and alternative data telemetry processes. The collection of meteorological data may often be required both prior to and during the remediation of contamination at an HTRW site. Meteorological data are often necessary to determine the potential risk to neighboring communities from contaminants released during the site remediation. Therefore, if representative meteorological data are not available from a neighboring National Weather Service (NWS) facility, these data will need to be collected on site.

Prior to the remediation of a contaminated HTRW site, an APA must usually be performed. The primary components of an APA are:

- Characterization of air emission sources (e.g., estimation of contaminant emission rates).
- Determination of the effects of atmospheric processes (e.g., transport and dilution).
- Evaluation of receptor exposure potential (i.e., what air contaminant concentrations are expected at receptors of interest for various exposure periods).

The overall goal of an APA is to evaluate the actual or potential effects of remediation on air quality. This evaluation is usually based upon the results of a computerized dispersion model of the effects of known releases of contamination from the HTRW site. Dispersion models usually require 1 year of representative wind data to define the path and concentration of the plume as a function of range from the site. If wind data are not available from the NWS, instrumentation probably will need to be established to collect it on-site.

The specific goal of any associated perimeter air monitoring network is to evaluate the potential exposure via the air pathway of residents and workers in neighboring communities to contaminants from the HTRW site. To determine this potential, the effects of measured releases on neighboring communities must be modeled. These models require meteorological data representative of the site during the episode. To complement the air monitoring network, instrumentation may be established on-site to collect meteorological data for site-specific windroses and receptor combinations.

b. Meteorological data collection and parameters. A meteorological station at a HTRW site must provide representative data for the area around the site and for each of the parameters required by dispersion models appropriate to that site. Careful consideration must be given to both the specification and siting of the appropriate equipment. The following sections contain discussions of meteorological station siting criteria, tower requirements, and the parameters to be measured.

(1) Siting criteria. The siting of a meteorological station is very important to the success of a remediation project. Siting of the meteorological station should follow guidance specified in three U.S. EPA documents:

- *Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. IV, Meteorological Measurements*, EPA-600/R-94/038d, Office of Research and Development, Research Triangle Park, NC, March 1995.

- *On-site Meteorological Program Guidance for Regulatory Modeling Applications*, EPA-450/4-87-013, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1987.

- *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)*, EPA-450/4-87-007, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1987.

As a general rule, the station should be sited away from the influence of obstructions such as trees and buildings and should be in such a position that it can make measurements that are representative of the HTRW site. Table 6-1 documents the key siting criteria, as provided from the above references, for properly locating long-term meteorological monitoring stations.

Table 6-1
Example of Key Siting Criteria for Meteorological Stations at HTRW sites

Factor	Criteria
1. Vertical Spacing Above	For long-term monitoring studies, sensors should be located 10 meters above the ground.
2. Horizontal Spacing	Optimum horizontal spacing for meteorological stations should be located away from nearby obstructions (trees, buildings, etc.) by a distance of 10 times the height of the obstruction.
3. Unrestricted Airflow	Unrestricted airflow must exist around the sensors.
4. Spacing from Roadways	Meteorological station must be placed at a distance greater than 25 meters from the edge of the nearest traffic lane.

The following are other practical guidelines for locating a meteorological station at a HTRW site:

- Locate the station in a portion of the site that allows for ease of access to security, power, and lighting.
- Meet siting criteria of 10 times the height of nearest obstructions (i.e., trees, buildings, etc.).
- Locate the meteorological station outside the exclusion zone to minimize intrusion into site during routine operation/ maintenance and quarterly audits of the system.

(2) Tower requirements. To representatively measure the wind speed and direction for the area around the HTRW site, meteorological wind sensors must be sited away from obstructions, as described above, and must be suspended 10 meters above the ground. A 10-meter, self-supporting meteorological tower should be erected on a 3-foot diameter by 3-foot deep concrete slab. This concrete slab will act as the anchor or primary support for the 10-meter meteorological tower. In addition, a lightening rod should be attached to the highest point on the tower and connected to the earth ground by a heavy copper wire, as illustrated in Figure 6-1.

(3) Meteorological parameters. Meteorological variables needed for most of the USACE and EPA computerized dispersion models include mean wind speed, wind direction, ambient air temperature and Pasquill stability category. The most accepted methods for determining stability category from HTRW sites are derived from (1) ambient air temperatures (i.e., measured at 2 and 10 meters) and solar radiation using the ΔT method, or (2) the standard deviation of the wind direction (σ_a). The measurement of precipitation, barometric pressure, and relative humidity in conjunction with ambient air monitoring at the HTRW site is highly recommended and is often a regulatory requirement. The time and date of each measurement must also be recorded. This section contains detailed information on the above meteorological variables.

Table 6-2 provides examples of system accuracy and measurement resolution for each of the measured meteorological variables. Locations of the specific instruments, frequency of measurements, units of measurements, required instrument accuracy, and measurement resolution for the meteorological instruments is included in this section.

Table 6-2
Example of System Accuracy and Measurement Resolution for Meteorological Systems at HTRW sites

Data Type	System Accuracy	Measurement Resolution
Wind Speed	+ or -0.5 m/s	0.1 m/s
Wind Direction	+ or -5°	1°
Ambient Temperature	+ or -0.5°C	0.1°C
Delta T (Vertical)	+ or -0.1°C	0.02°C
Radiation	50 W/m^2	10 W/m^2
Precipitation	+ or -0.5 mm	0.3 mm
Time	+ or -5 minutes	

Wind speed is one of the primary variables needed for a dispersion modeling analysis. It determines the amount of initial dilution encountered by the plume exiting the emission source, as well as the amount of plume rise. An instrument to measure wind speed should be located on the meteorological tower at a height of 10 meters above the ground surface (see Figure 6-1). Observations should be recorded continuously; at 1-hour intervals, the mean wind speed with standard deviation, and maximum and minimum values should be calculated. The wind speed should be recorded in units of meters per second (m/s) within a range of 0 to 20 m/s.

The wind direction, for meteorological purposes, defines the direction from which the wind is blowing and is measured in degrees clockwise from true North. Wind direction determines the direction a plume will travel. The instrument to measure wind direction should be located on the meteorological tower at a height of 10 meters above the ground surface, as illustrated in Figure 6-1. The wind direction should be recorded continuously; at 1-hour intervals; the mean wind direction and the standard deviation of wind direction should also be calculated. The wind direction should be recorded in units of degrees with an instrument resolution to the nearest 1°.

Figure 6-1. Example of a 10-meter meteorological station at a HTRW site

Because of problems associated with averaging wind direction as the vane crosses over the North (i.e., 0 to 360°), a 0° to 540° instrument should be used.

The ambient air temperature is used in determining the amount of rise experienced by a buoyant plume. If the ΔT method is used to calculate the Pasquill stability category, the ambient air temperature should be measured at both 2 meters and 10 meters above the ground, as illustrated in Figure 6-1. The temperature sensors should be housed in aspirated enclosures. The temperature at 10 meters and optionally the ΔT should be measured continuously; at 1-hour intervals, the mean temperature and ΔT, with maximum and minimum values, should be calculated. The temperature and ΔT should be recorded in units of degrees Celsius (°C) and converted to degrees Kelvin (K) for model input purposes. The ambient air temperature measurements are generally made over a nominal range of -50° to +50°C.

Solar radiation, which is related to the stability of the atmosphere, should also be measured at the meteorological station. As stated earlier, the solar radiation could be used with the ΔT measurement to estimate the stability category. The instrument measuring solar radiation should be mounted as the highest instrument at the 10-meter level above the ground, as illustrated in Figure 6-1. The solar radiation should be measured continuously; at 1-hour intervals, the mean, maximum, and minimum values should be calculated. The solar radiation should be recorded in units of watts per meter squared (W/m^2) with a measurement resolution of 10 W/m^2.

Barometric pressure (P_{bar}) and relative humidity (RH) are not typically required to perform dispersion modeling. However, this data is required to calculate air density and are often useful in the calibration of ambient air monitoring equipment as part of the FFMS. A meteorological station at an HTRW site should include these sensors. Both P_{bar} and RH should be measured continuously; at 1-hour intervals, the mean values should be recorded. The P_{bar} should be measured in units of mBars and the RH in units of percent moisture. The P_{bar} measurements should be made within a range of 800 to 1100 mBars, resolved to the nearest mBar, and accurate to within ±5 mBars. The RH measurements should be made within a range of 0 to 100 percent RH, resolved to the nearest percent, and accurate to within ±5 percent.

Precipitation should be recorded at the HTRW site even though it will not be used by the dispersion model. The precipitation measurements are useful information during remediation activity and for the data review and validation process. The precipitation gauge should be at least 6 inches in diameter and should be heated for winter operation. The precipitation gauge should be located away from the tower (10 meters), positioned on a level platform about 1 meter above ground. In some climates, a snow fence is suggested around the precipitation gauge. Precipitation should be totalized continuously; at 1-hour intervals, the total value should be recorded. Precipitation measurements should be made in units of inches. The selected instrument should measure precipitation within a range of 0 to 100 inches and accurate to within 0.1 inch.

A secondary parameter used in dispersion models requires the operator of the meteorological station and FFMS to calculate stability categories as indicators of atmospheric turbulence.

The amount of turbulence in the atmosphere has a major impact on the rise of on-site emission plumes and upon their subsequent dispersion by diffusion. Turbulence is a result of many factors, including windflow over rough terrain, trees, or buildings (mechanical turbulence); rising warm air (thermal turbulence); and migrating high and low pressure air masses. Any factor enhancing the vertical motion of air will increase the amount of turbulence. For a given wind speed, stable atmospheric conditions provide smaller levels of atmospheric turbulence than do unstable conditions and can lead to higher model-predicted concentrations.

For site perimeter impacts, dense gas releases will only be weakly affected by stability classification. As the release becomes neutrally buoyant, the plume will become more influenced by atmospheric conditions such as stability class.

Dispersion models currently use stability categories as indicators of atmospheric turbulence. Based on the work of Pasquill and Gifford, six stability categories have been defined, where Category A represents extremely unstable conditions and Category F represents moderately stable conditions. Methods for estimating atmospheric stability categories from on-site data are provided in the *Guideline on Air Quality Models (Revised) and On-Site Meteorological Program Guidance for Regulatory Modeling Applications*. The Pasquill-Gifford (P-G) stability classification method attempts to parameterize the results of turbulence in the atmosphere (stability) using observations of wind speed and subjective estimates of incoming solar radiation. The Pasquill categories are:

Pasquill Categories	Stability Classification
Extremely unstable	A
Moderately unstable	B
Slightly unstable	C
Neutral	D
Slightly stable	E
Moderately stable	F
Extremely stable	G

Modeling guidelines published by EPA identify four methods of using on-site data to determine the Pasquill stability class of a parcel of air at a HTRW site. In order of preference, these methods are:

- Turner's 1964 method using site-specific data, which include cloud cover, ceiling height, and surface (~10 meters) wind speeds.
- Vertical wind direction fluctuations (σ_e) from site-specific measurements. σ_e may be determined from elevation angle measurements or may be estimated from measurements of σ_w according to the transform: $\sigma_e = \sigma_w / \mu$.
- Horizontal wind direction fluctuation (σ_a) from site-specific measurements.
- Turner's 1964 method using wind speed with cloud cover and ceiling height from a nearby NWS site.
- Temperature changes with altitude. Two thermocouples positioned at the 10- and 2-meter location to give a ΔT output.

Turner's 1964 Method with Site-Specific Data. Turner provided an objective method for implementing the P-G method using routine airport observations. Stability using Turner's method is a function of wind speed and Turner's net radiation index. The latter is dependent on cloud cover and ceiling and the solar insolation class, which is a function of the solar elevation angle and is objectively determined based on location and time.

Turner's method in combination with the P-G stability categories provide practical procedures for routinely implementing the Gaussin dispersion models. By virtue of its historic precedence and widespread use, EPA considers Turner's method to be the benchmark procedure for determining P-G stability.

Vertical Wind Direction Fluctuations (σ_e). Next to the Turner 1964 system employing on-site observations, the EPA prefers that stability be determined from vertical wind direction fluctuations (σ_e). The most economical way of measuring vertical wind speed fluctuations is to install a lightweight propeller on a vertical axis. The propeller will rotate, first, one way and then the other as the air mass is alternatively buoyant and subsiding. Another way to measure vertical wind fluctuations is to use a bivane that pivots on a single point and has a circular band on the tail instead of the usual fins. The bivane will tilt in response to the combinations of vertical and horizontal winds. Further details, including the calculational procedure for vertical velocity fluctuations, can be found in EPA's *"On-Site Meteorological Program Guidance for Regulatory Modeling Applications."*

Horizontal Wind Direction Flucutation (σ_a). Next in order of EPA preference for determining stability is the method based on horizontal wind direction fluctuations. In contrast to vertical fluctuations, the equipment to measure horizontal fluctuations is more reliable. A low mass wind vane is used in conjunction with a micro-computer to determine the standard deviation of the horizontal meander.

Turner's 1964 Method Using NWS Data. This method is similar to the Turner 1964 Method except NWS data is used in place of site-specific data. This is the least favored of the methods because there is generally a lack of proximity of a NWS to a HTRW site.

Temperature Change (ΔT) with Altitude. Temperature measurements made at two different elevations (i.e., 10- and 2-meter height) can be used to determine stability. This method normally employs a tower with motor-driven fans (aspirators) and a highly sensitive thermocouple or thermistor that measures the temperature differences. The use of this method is approved by the Nuclear Regulatory Commission but not by the EPA. The releases from nuclear facilities generally have no plume rise and occur at elevations of 30 to 45 meters. The emissions from warm stacks that are of greatest interest to EPA result in plume elevations of 50 to several hundred meters. The EPA believes that the ΔT scheme does not adequately assess the stability in the boundary layers in which most of its plumes disperse.

For fugitive sources and toxic gas releases that occur without plume rise, the ΔT method may provide a reasonable way of determining stability.

Finally, the solar radiation measurement can be combined with the ΔT to determine atmospheric stability at the site. The solar radiation/Δ-T (SRDT) method retains the basic structure and rationale of Turner's method, while eliminating the need for observations of cloud cover and ceiling. It is the recommended alternative procedure for use with on-site data.

The SRDT method (see Table 6-3) uses the 10 meter wind speed in combination with measurements of total solar radiation during the day and temperature difference (ΔT) at night. The method is based on Bowen (1983) with modifications as necessary to retain as much as possible of the structure of Turner's method as implemented in the EPA's recommended meteorological processors: *Meteorological Processor for Regulatory Models (MPRM) and RAMMET*. Results of an evaluation using three on-site data bases (19,540 combined valid hours) show that the SRDT method estimates the correct P-G stability category 62 percent of the time and is within one category of the P-G stability 89 percent of the time.

The stability classification method recommended for use at HTRW sites for a FFMS is either the horizontal wind direction fluctuation (σ_a) or the temperature change (ΔT) in conjunction with solar radiation measurement.

Communication process. Electronic signals provided by each of the meteorological instruments should be interpreted, summarized, and stored in a data logger intrinsic to the meteorological station. However, if real time ambient air monitoring is being performed as part of a FFMS, these data should be exported to the Air Monitoring Data Acquisition/Telemetry System (AMDAS) in the Analytical Center. This process allows access to air quality data from the FFMS which can be combined with meteorological data to provide real time upwind/downwind evaluation capability so site activities can be modified to reduce emissions during remediation.

If this method is selected, a data path must be established between the meteorological tower and the AMDAS. Three common methods of providing this path are:

- If the meteorological tower and the AMDAS are in close proximity to each other (~15 meters), signal conditioners can be used to convert the electrical signal from each instrument to an electrical current loop (i.e., 4 to 20 mA). These conditions would be connected directly to the AMDAS in the Analytical Center

- If there is an unobstructed line of site between the meteorological tower and the AMDAS in the Analytical Center but it is not practical to use a data cable to connect them, a small data logger can be used to digitize the electrical signal from each instrument so it could be transmitted to the AMDAS using a pair of frequency modulated radio modems.

- If however, there is not an unobstructed line of site between the meteorological tower and the AMDAS and it is not practical to use a data cable to connect them, or if there is no AMDAS, a small data logger can be used to digitize the electrical signal from each instrument so that it can be transmitted to the AMDAS or a reporting computer using telephone modems and a commercial telephone line.

Table 6-3
Example of Use of Solar Radiation/Delta-T (SRDT) Method for Estimating Pasquill-Stability Categories

Wind Speed (m/s)	DAYTIME Solar Radiation (Wm $^{-2}$)			
	≥925	675 → 925	175 → 675	<175
<2.0	A	A	B	D
2.0 → 3.0	A	B	C	D
3.0 → 5.0	B	B	C	D
5.0 → 6.0	C	C	D	D
≥6.0	C	D	D	D

Wind Speed (m/s)	NIGHTTIME Temperature Difference (°C)	
	<0.0	≥0.0
<2.0	E	F
2.0 - 2.5	D	E
≥2.5	D	D

c. Data and reporting formats. Most modern DAS offer a host of reporting options for meteorological data. These reformatted reports meet the reporting requirements of most HTRW site meteorological monitoring applications. However, if specialized reporting is required, report writing languages are usually available to meet these needs.

A typical menu of reformatted reporting options could includes categories such as:

- Daily summary report.

- Status reports.
- Historical reports
- Graphs.
- EPA reports.

The measurements taken at the meteorological station should be recorded and stored on a DAS located in the Analytical Center. The DAS is one of the most important components of the meteorological program. The main function of the DAS is to collect air quality data (including meteorological data,) process and store the data, and report this data, which is then used as part of the HTRW site assessment. Data turnaround times are most stringent when the monitoring data are being compared with short-term action levels during remediation. In these cases, immediate or real-time monitoring of meteorological parameters are usually required. At a minimum, a daily summary report should be available for evaluation by the on-site personnel. The daily summary report should, at a minimum, include the following:

- Hourly averages for wind speed (m/sec), wind direction (degrees), stability class, 10-meter temperature ($^{\circ}$C), barometric pressure (mBars), and precipitation (inches).
- Minimum, maximum, and average values for each of the parameters monitored.
- Indication of missing data points.

Figure 6-2 illustrates a typical daily HTRW site meteorological report.

Status reports generally refer to reports of the status of instrumentation, alarms, or data, as it is provided to the data logger. Historical reports get their data from the archived data files. Graphs, USACE, and EPA reports are specialized forms of historical reports.

Status reports should be generated if short-term action levels are exceeded by any of the individual data points. These data should then be used in conjunction with dispersion models. These data should be used to validate the model outputs for the HTRW site. This validation is done by comparing measured ambient air concentrations from the FFMS to the concentrations predicted by an atmospheric dispersion model that uses the actual meteorological conditions present during monitoring.

Dispersion models are inherently conservative, so the model output will usually over-predict ambient concentrations. The degree to which the model over (or under) predicts will depend on site-specific factors. The degree of over-prediction observed for a short-term dispersion modeling may be used, with limitations, as a correction factor when interpreting long-term dispersion modeling results.

Some useful examples of reformatted historical reports available with an integrated data acquisition system might include:

- Frequency Distribution Report — generates a frequency distribution report of a selected pollutant from the hourly data files. An averaging interval may be specified by the operator.
- Joint Frequency Distribution — generates a joint frequency distribution report and a wind or pollution rose on the screen, as illustrated in Figure 6-3.

- Data Recovery Report — prints out a report showing the number and percentage of valid scans from all instruments. The time period is defined by the operator.

- Calibration Report — generates a report that shows the zero and span data for all auto-calibration instruments.

Some examples of reformatted graphical reports available with an integrated DAS might include:

- Daily Two Parameter Graph — displays hourly averages for a selected day and parameter (see Figure 6-4).

- Five-Day Single Parameter Graph — displays hourly averages for a selected 5 days and parameter (see Figure 6-5).

- Monthly Single Parameter Graph —displays hourly averages for a selected month and parameter with zoom features to a selected 5-day span.

- Daily Multiple Site Graph— displays hourly averages for selected sites (up to 5) on one graph for a selected day.

- Five-Day Multiple Site Graph — displays hourly averages for selected sites (up to 5) on one graph for 5 days.

- Daily Multiple Parameter Graph — displays hourly averages for selected parameters (up to 3) on one graph for a selected day.

- Five-Day Multiple Parameter Graph — displays hourly averages for selected parameters (up to 3) on one

- Calibration Graph for One Month — displays calibration values for one parameter for 1 month. (Zero, Span 1, and Span 2 are all displayed on one graph.)

d. Data QA/QC. A comprehensive QA/QC program for the operation of a meteorological station at a HTRW site should include both (1) a timely and comprehensive review and validation of the data and (2) a rigorous inspection, maintenance, and calibration program.

(1) Data review. At regularly scheduled intervals, data must be downloaded from a meteorological station's data logger, reviewed for completeness and reasonableness, archived, and reported. These activities should be performed daily if possible and should not be performed less than once per month. If possible, data should be compared with climatological data from a nearby NWS station. If any missing or unreasonable data is identified, a corrective action report (see Figure 6-6) and a corrective action request (see Figure 6-7) should be completed and included in the DCQCR.

(2) Calibration procedures. The meteorological station should be factory calibrated prior to initial shipment to the site and at least once every 2 years thereafter. In addition, every time the meteorological station

is installed, and quarterly during its operation, the sensors should be checked for damage and all parameters should be verified as correct. Set-up and quarterly audits should be performed using their transfer standards listed in Table 6-4.

At the completion of a field verification, a site calibration report (see Figure 6-8) should be completed and included as part of the Site Inspection Form (see Figure 6-9). If any discrepancies are noted, a corrective action report and a corrective action request must also be completed and included in the DCQCR.

The remainder of this section describes a generic HTRW on-site maintenance program for the meteorological system that should be performed immediately following installation and quarterly thereafter.

Daily Meteorological Monitoring Report at a USACE HTRW site, Anytown, USA
Date: 30 Sep 96
Time: 00:00 to 23:00

Time	Wind Speed, (m/sec)	Wind Direction, °	Stability Class (A, B, C, D, E, F)	Temp., °C	Barometric Pressure, mB	Precipitation, inches.
00:00	1.4	292	F	12.1	995	9.60
01:00	1.0	261	E	10.5	995	9.59
02:00	0.9	239	E	9.1	995	9.59
03:00	0.7	265	F	8.6	995	9.59
04:00	0.8	266	F	8.0	995	9.59
05:00	1.0	306	F	8.0	996	9.59
06:00	0.8	316	F	7.6	996	9.59
07:00	1.7	329	A	8.5	996	9.59
08:00	2.0	342	B	9.4	996	9.59
09:00	1.2	340	A	10.8	996	9.59
10:00	1.0	336	A	13.2	996	9.60
11:00	1.1	97	A	15.8	995	9.60
12:00	1.6	77	A	18.8	994	9.60
13:00	2.0	83	A	21.6	993	9.60
14:00	2.1	88	B	23.3	991	9.60
15:00	1.7	105	A	24.6	990	9.60
16:00	1.7	116	D	24.6	989	9.60
17:00	1.4	102	F	23.3	989	9.60
18:00	2.0	138	F	33.2	989	9.60
19:00	1.8	142	F	22.7	989	9.60
20:00	1.7	150	F	22.6	989	9.60
21:00	1.6	176	F	22.2	989	9.60
22:00	2.5	215	E	21.7	989	9.60
23:00	2.4	233	D	31.3	988	9.60
MAX	3.4	342		24.6	996	9.60
MIN	0.7	77		7.6	988	9.59
SIGMA	0.6	95		6.6	3	0.00
AVG	1.5	211		16.3	993	9.60
GOOD	24.0	24		24.0	24	24.00

Figure 6-2. Example of daily meteorological report for a HTRW site

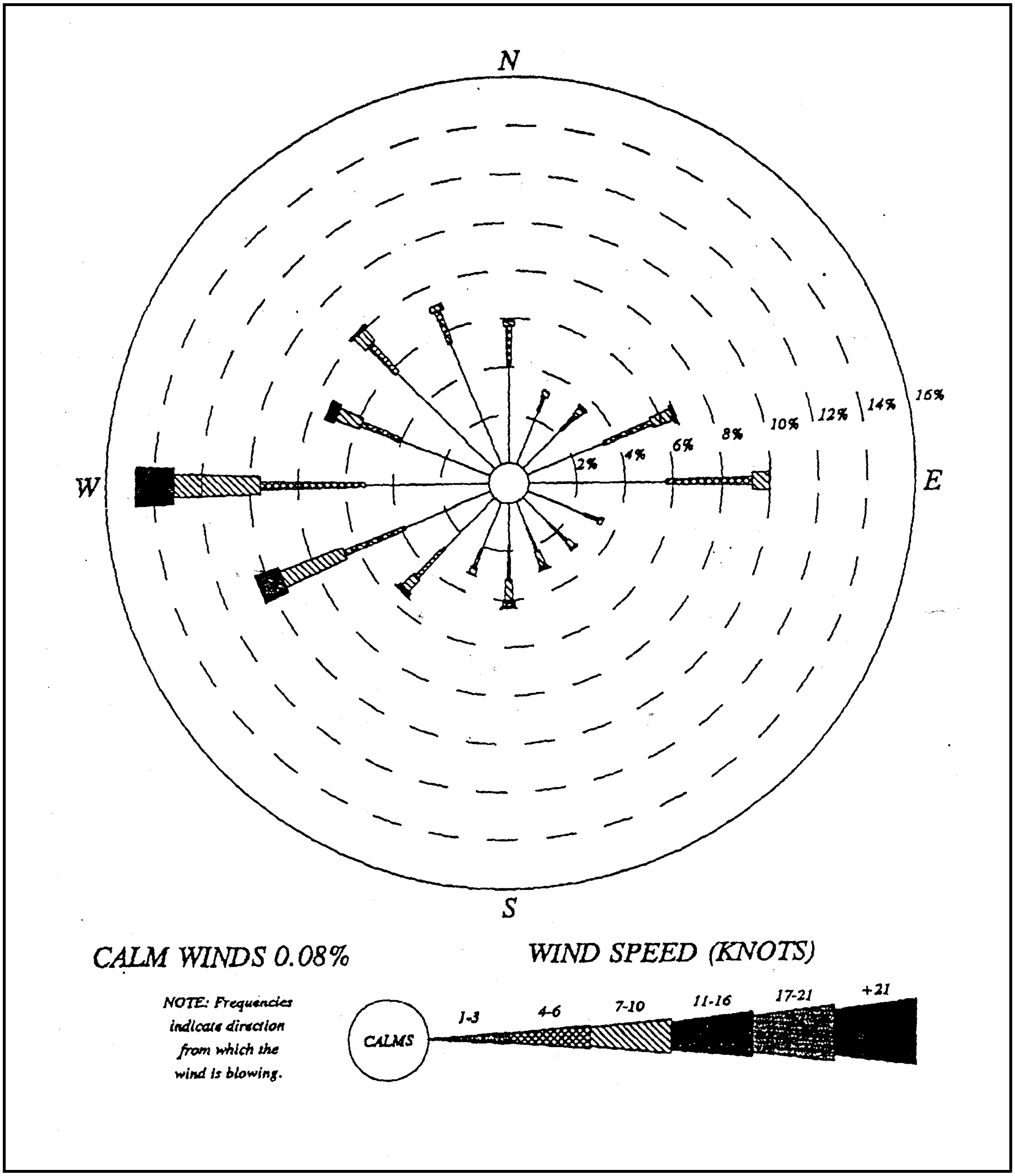

Figure 6-3. Example of typical meteorological display (wind rose) of wind speed and direction

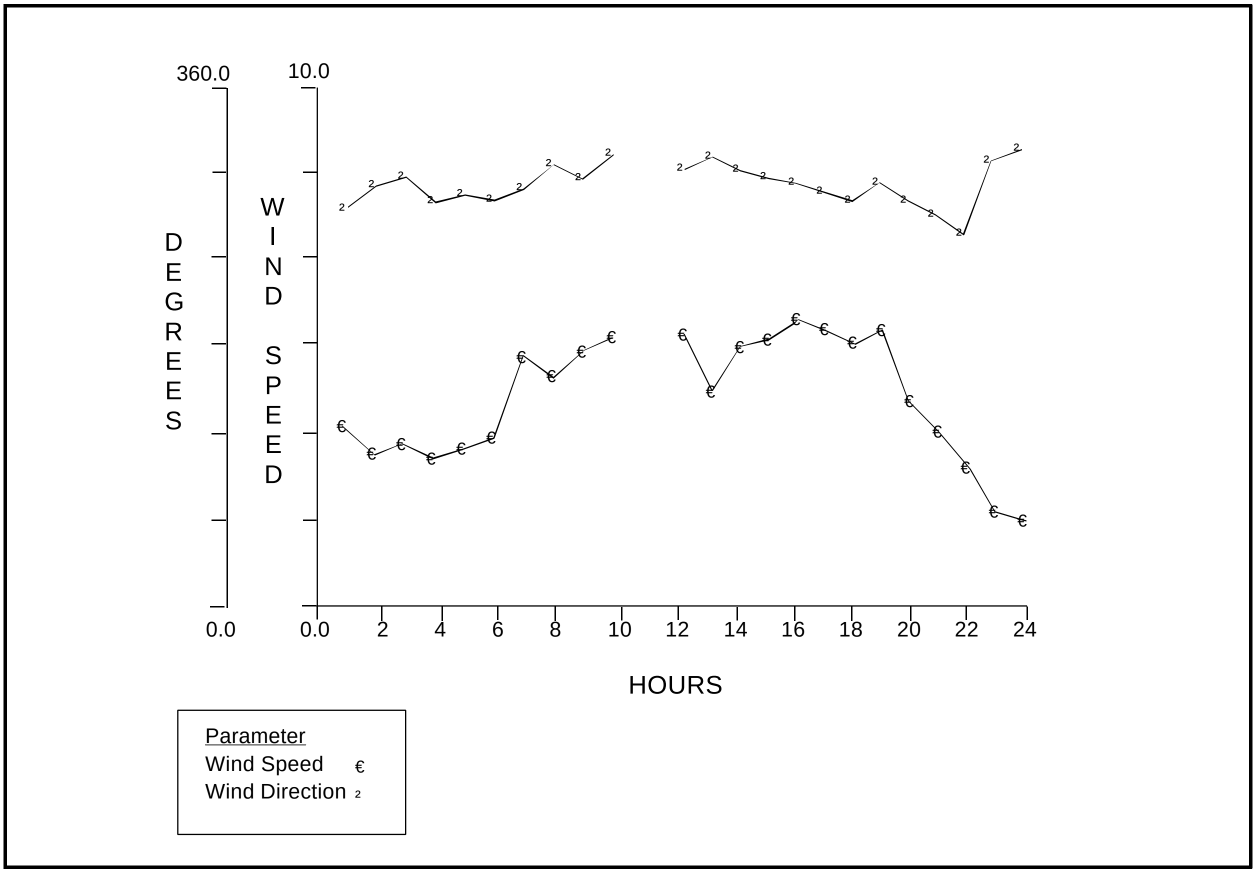

Figure 6-4. Example of meteorological report illustrating daily two parameter graph for a HTRW site, Any Town, USA

(a) Tower, enclosures, and cables. Before verifying the accuracy of the meteorological instrumentation, conduct a check of the support hardware necessary for its functionality. Using a carpenters lever, verify that the tower is level. If it is not, shims must be inserted below the tower and guide wires tightened to correct the problem. Verify that all electrical cables are firmly attached and not free to blow in the wind. If any electrical cables are loose, attach them to adjoining hardware. Verify that all weather-tight enclosures are closed and properly sealed. Check to see that fans on electronic cabinets or aspirated enclosures are operating properly.

(b) Wind speed anemometer. Check the physical integrity of the anemometer cups, shaft heater (i.e., if installed), and electrical cables. Replace any damaged equipment. Check to see if the cross-arm is level and if the anemometer spins easily and smoothly. Remove the

Table 6-4
Standard Certification Instrumentation for Meteorological Station Audits

Parameter		Verification Method
1.	Wind Direction	Compass
2.	Wind speed	Frequency monitored servo motor
3.	Temperature	Mercury in glass thermometer
4.	Relative humidity	Sling psychrometer
5.	Precipitation (rain gauge)	Graduated container

anemometer cups from the shaft and attach a thumb-wheel torque gauge (i.e., usually available from the instrument manufacturer) to ensure that the starting torque is less than the operating specification for the anemometer. Remove the thumb-wheel torque gauge and attach a frequency monitored servomotor (i.e., usually available from the instrument manufacturer) to verify that the indicated wind speed is within the accuracy specified by the instrument manufacturer. Repair or replace any damaged or worn parts. Attach the anemometer cups to the shaft. If any adjustments are necessary to the signal conditioning board, reset the zero and span according to the manufacturers recommended procedures.

(c) Wind vane. Check the physical integrity of the wind vane, shaft heater (i.e., if installed), and electrical cables. Replace any damaged equipment. Check to see if the cross-arm is level, aligned with the North, and if the vane spins easily and smoothly. Remove the wind vane from the shaft and attach a thumb-wheel torque gauge (i.e., usually available from the instrument manufacturer) to ensure that the starting torque is less than the operating specification for the instrument. Remove the thumb-wheel torque gauge and replace the wind vane. Hold the wind vane in each of the cardinal directions while checking the accuracy of the indicated wind direction. Hold the wind vane in each of two known directions for consecutive halves of an integration period to verify the calculated standard deviation of wind direction. Repair or replace any damaged or worn parts. If any adjustments are necessary to the signal conditioning board, reset the zero and span using the manufacturers recommended procedures.

(d) Temperature sensor(s). Check the physical integrity of each temperature sensor, the enclosures, the fans (i.e., if installed), and the electrical cables. Verify the temperature indicated by each instrument against a National Institute of Standards and Technology (NIST) traceable thermometer with 1/10° F graduations, placed within the aspirated enclosure. If any adjustments are necessary to the signal conditioning board, reset the zero and span using the manufacturers recommended procedures.

(e) Barometer. Check the indicated station barometric pressure against a NIST traceable aneroid barometer or the station pressure reported by a nearby NWS reporting station at roughly the same altitude. If any adjustments are necessary to the signal conditioning board, reset the zero and span using the manufacturers recommended procedures.

(f) Relative humidity sensor. Check the indicated relative humidity against a sling psychrometer equipped with NIST traceable thermometers and a psychometric chart. If any adjustments are necessary to the signal conditioning board, reset the zero and span using the manufacturers recommended procedures.

(g) Precipitation gauge. Check the physical integrity of the rain gauge, heater, snow fence (if installed), and electrical cables. Verify that the rain gauge is level, that the mechanism moved freely, and that the rain path is free from obstructions. Slowly pour a known volume of water into the rain gauge. Divide the volume of water introduced by the area of the top of the rain gauge for comparison with the indicated amount of rainfall from the DAS in the Analytical Center.

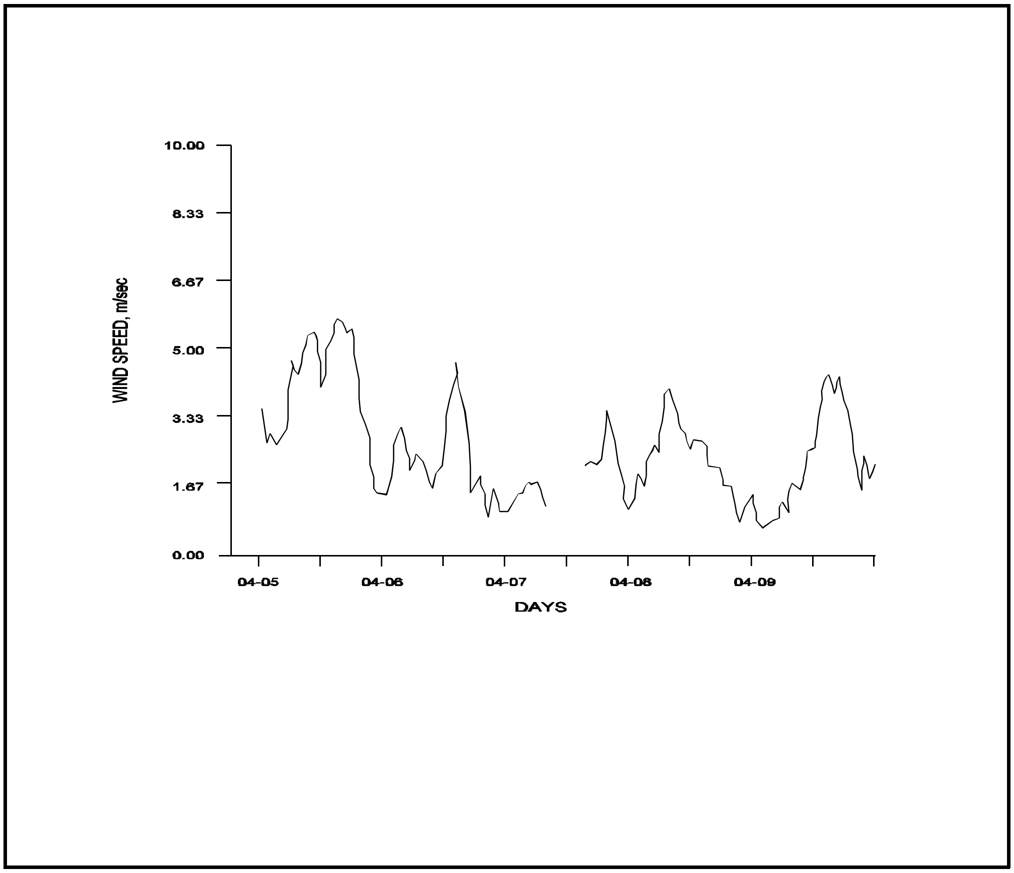

Figure 6-5. Example of meteorological report illustrating 5 day single parameter (wind speed) graph for a HTRW site, Any Town, USA

CORRECTIVE ACTION EXAMPLE
USACE HTRW SITE
ANY TOWN, USA

Originator's Name ______________________________ Date ______________
Reporting Facility ______________________________ Refs. ______________

Component ____

Failure found in:

☐ Installation ☐ Calibration ☐ Operational Use
☐ Unit Test ☐ System Test ☐ Service Call
☐ Other ______

Originator's Statement of Failure

Corrective Action Required in Field

Name Date

Corrective Action Request
(see Figure 6-7)

DISTRIBUTION

☐ Quality Assurance ☐ Project Manager
☐ Field Operations ☐ FILE
☐ Data Processing

Figure 6-6. Example of corrective action report for a HTRW site meteorological program

CORRECTIVE ACTION REQUEST EXAMPLE
USACE HTRW SITE
ANY TOWN, USA

Originator/Dept ____________Site Name ______________________________
____________Site No. ____
Part No. ____________Part Name ___________________________________
Quantity ____________ P.O. No. _________ Serial No. _________ R/R No. ______
Discrepancy: ____
____
____
____
____

Signature: ____________________________Date _______________________

CORRECTIVE ACTION

Cause of Discrepancy: ____
____
____
____
Action Taken to Prevent Recurrence: ________________________________
____
____
____

Correction Action is: ☐ APPROVED ☐ DISAPPROVED
Corrective Action Verified As Accomplished ☐

Signature: ____________________________Date _______________________

DISTRIBUTION

☐ Quality Assurance

☐ Project Manager

☐ Field Operations

Figure 6-7. Example of corrective action request for a HTRW site meteorological program

SITE CALIBRATION EXAMPLE
USACE HTRW SITE
ANY TOWN, USA

Customer Name ________________ Arrive Time/Date ________________
Site Name/I.D. ________________
Met Level _______ of _______ Levels.

I. Met System Information:
Manufactured By ________________ Model No. ________
Wind Speed Sensor Type ________________ Serial No. ________
Wind Direction Type ________________ Serial No. ________
Translator Model No. ________________ Serial No. ________

2. Condition of Met System:
W/S Sensor ________________ Cups ________
W/D Sensor ________________
Signal Cables ________________
Translator ________________
Orientation ________________

3. Calibrator:
Manufactured By ________ Model No. ________ Serial No. ________

4. Before Calibration:

W/S/ Signal	SW Position	Expected	Actual Speed	=	Chart (Opt)
	1.				
	2.				
	3.				
	4.				

W/S/ Signal	SW Position	Expected Outlet	Actual Output	=	Chart (Opt)
	0	0 V			
	•	1.5 V			
	•	3.2 V			
	F	4.3 V			

5. After Calibration (If Required):
Reason: ________________

W/S/ Signal	SW Position	Expected	Actual Speed	=	Chart (Opt)
	1.				
	2.				
	3.				
	4.				

6. Upon Completion of All Calibrations, This Site Mark Tape With “Calibration Data”

Calibration Performed By ________________
Date/Completion Time ________________
Calibration ________ of ________ this location ____
Regional Office ________________

Figure 6-8. Example of site calibration for a HTRW site meteorological program

SITE INSPECTION EXAMPLE
USACE HTRW SITE
ANY TOWN, USA

Time Arrived ______________________

Customer Name ______________________

Site Name/I.D. ______________________ Location ______________________

No. of Levels ______________________

Type of Inspection:

Weekly Monthly Quarterly Bi-Annual Actual

1. Condition of met System:
   Met Model ______________________ S/N ______________________
   Manufactured By ______________________
   Sensors O.K.? ______________________
   Cups O.K.? ______________________ If No. Explain ______________________
   Vane O.K.? ______________________ If No. Explain ______________________
   Cables O.K.? ______________________ If No. Explain ______________________
2. Met Conditions:
   Wind Blowing? __________ Cloud Cover ( ) __________ Temp., °F ______________________
3. Met System:
   If Wind Blowing, Are Cups Moving? Level 1 ________ Level 2 ________
   Are Vanes Deflecting? Level 1 ________ Level 2 ____ Level 3 ______________________
4. Chart Recorder:
   Manufactured By ______________ Model ______________ S/N ______________
   Chart Speed ________ Chart Time: Gain ________ Loss ________ (i.e., Minutes)
5. Data Logger:
   Manufactured By ______________ Model ______________ S/N ______________
   Tape Started, Time/Data ______________________ Ended, Time/Date ______________________
   Tape Ran O.K.? ______________________ Error Signal ______________________
6. Power Supply:
   Batteries O.K.? ______________________ If No, Explain ______________________
   Voltage Level ______________________ If Failure, Approx. Time/Date ______________________
7. Station Check Information:
   Time Departed ______________________ Total Time ______________________
   State Checked By ______________________ Affiliation ______________________

Figure 6-9. Example of site inspection for a HTRW site meteorological program

(h) Telemetry process. Once a working meteorological station and data logging system are established, a data path must be established between the meteorological tower and the DAS in the Analytical Center used for data review, archiving, and reporting. Three common methods of providing this path are:

- If the meteorological station is unattended, the data logger and the data reduction computers can each be equipped with a dial-up telephone modems. The DAS can be used to call the station data logger and download data. The data can then be reviewed, reduced, and reported from the convenience of a remote location.

- If the meteorological station is attended and the data review, reduction, and reporting will be conducted on-site as part of the Analytical Center, the data can be downloaded by a standard serial or parallel computer interface to the on-site computer in the Analytical Center.

Table 6-5
Suggested Data Screening Criteria for a Meteorological System at a HTRW Site

Meteorological Variable	Screening Criteria (Flag data if the value:)
Wind speed	• Is less than zero or greater than 25 m/s • Does not vary by more than 0.1 m/s for 3 consecutive hours • Does not vary by more than 0.5 m/s for 12 consecutive hours
Wind direction	• Is less than 0 or greater than 360° • Does not vary by more than 1° for more than 3 consecutive hours • Does not vary by more than 10° for 18 consecutive hours
Temperature	• Is greater than the local record high • Is less than the local record low; (the above limits could be applied on a monthly basis) • Is greater than a 5° change from the previous hour • Does not vary by more than 0.5°C for 12 consecutive hours
Temperature difference	• Is greater than 0.1° C/m during the daytime • Is less than -0.1° C/m during the nighttime • Is greater than 5.0° C/m or less than -3.0°C/m

- If the meteorological station is attended but the data review, reduction, and reporting will be conducted off-site, the data can be downloaded as described in methods (1) or (2) above. If the data is downloaded on-site, as described in method (2), the data files could be copied to disks and mailed, downloaded to the remote location using a direct modem link, or downloaded through a corporate bulletin board service or the Internet.

(i) Processing of on-site meteorological data for modeling. The first review of the data involves a screening to identify suspect data points. The screening criteria are outlined in Table 6-5 for various meteorological parameters. Once the meteorological data has been screened and certified as accurate, it may be used in future dispersion models. The EPA has recently issued guidance on the use of meteorological data, collected via an on-site measurement program, for regulatory modeling applications. The meteorological processor currently available from EPA is the MPRM. The MPRM, Version 1.2, has been designed to construct meteorological data files of upper air, mixing height, surface observations, and on-site data for air pollution dispersion models that are routinely used in regulatory decision making by EPA. Specifically, the processor is designed to accommodate those dispersion models recommended for use in the *Guidelines on Air Quality Models*.

As illustrated in Figure 6-10, the MPRM, Version 1.2, consist of a three-stage processing system:

(1) First stage processor (extraction and quality assessment). During the first stage, the processor extracts upper air, mixing height and surface data from the raw data files delivered from the National Climatic Data Center (NCDC) in Asheville, North Carolina, and on-site data from the raw data files developed from the on-site meteorological station. The extracted data are processed through a series of quality assessment checks. Missing and suspect values are identified and reported.

Consequently, the goal of this first stage of processing is to:

- Read the on-site and NWS meteorological data files.
- Find the data within the time period specified by the user.
- Store these data in American Standard Code for Information Interchange (ASCII) data files.
- Scan the stored values and report occurrences of missing or suspect values.

An additional capability of this first stage is assessing the quality of the data by checking for possible missing or suspect values. Any occurrences of missing or suspect data values are reported before the upper air soundings, mixing height data, surface observations, and on-site data are combined.

The output files from this first stage of processing should be edited using standard text

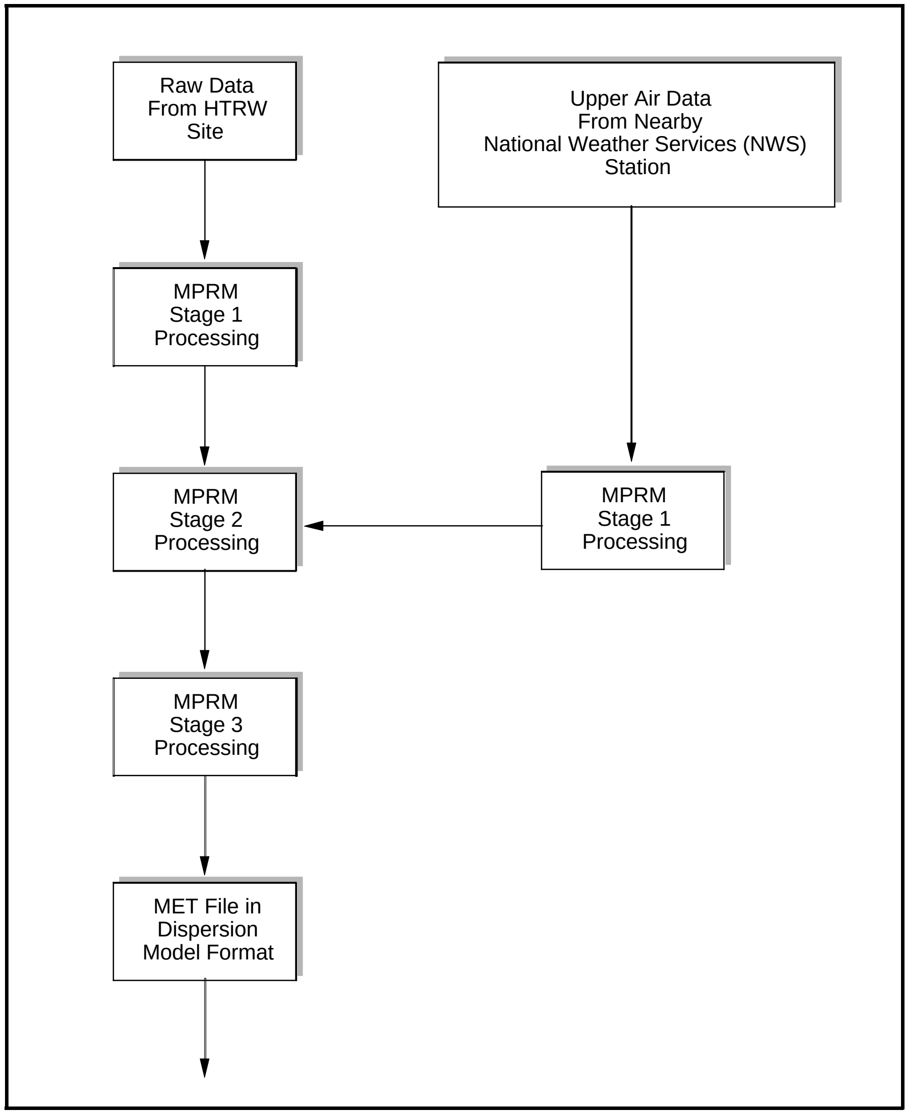

Figure 6-10. Example of EPA's three stage meteorological data processing, MPRM Version 1.2

editors routinely available on computer systems.

(2) Stage 2 processor (combining data). During the second stage, the processor combines the available data for each midnight-to-midnight, 24-hour period (twice-daily upper air soundings and mixing height data, hourly surface weather observations, and hourly on-site data) and stores these data in a combined (merged) format.

The goal of the second stage of processing is to:

- Combine into one file the available onsite and NWS meteorological data files created during Stage 1 processing.

- Store the data in a more compact format.

For specifying the dispersive state of the atmosphere, the physics of the atmosphere should be considered daily. Estimation of the depth of convective mixing (atmospheric stability) is the summation of effects starting with the heating of the surface shortly after sunrise. Thus, the merging of the available data for each 24-hour period is the next logical step in processing before developing the characterization of the input meteorological data files for the dispersion models.

The merged data are stored in unformatted form because this format is a more efficient use of storage than the formatted ASCII data file storage that is used during the first stage of processing. The ASCII files are convenient for test editors but are no longer needed once the quality assessment and editing are completed.

(3) Stage 3 processor (creating a model input file). During the third and final stages, the processor reads the merged data and develops a meteorological data file for the dispersion model selected by the user. The goal of this third stage is to create a meteorological data file for use with a regulatory dispersion model chosen by the user.

The MPRM can generate one of several output formats to meet the input requirements of the regulatory dispersion model chosen by the user. The RAMMET format can be selected as the default output with default methods for processing wind, temperature, stability category, and mixing heights. These methods employ the NWS hourly surface weather observations and the NCDC twice-daily mixing heights and duplicate the processing performed by the RAMMET meteorological processor.

6-3. Integration of Analytical System and Sample Collection System with Meteorological Monitoring

a. Introduction. Electronic signals provided by each of the on-site meteorological station could be interpreted, summarized, and stored in a data logger intrinsic to the meteorological station. If real-time information is needed, however, those data should be exported to a DAS located in the Analytical Center, as illustrated in Figure 6-11.

b. System network and design . Integrating and managing the meteorological data at a DAS within the Analytical Center ensures that the program objectives associated with meteorological parameters are met. At a minimum, the central DAS provides:

- Storage of all required meteorological data.

- Ability to enter and access pollutant-specific data with the meteorological data to generate histograms.
- Retrieval of data and preparation of standardized reports.

As identified in Figure 6-11, the analog inputs from the meteorological station for instruments measuring wind speed, wind direction, temperature, solar radiation, barometric pressure, and relative humidity are attached to the central DAS in the Analytical Center for storage and future reporting. The programs available allow the data to be retrieved and stored in 1-minute, 5-minute, 30-minute, or 1-hour averages. The user determines which averaging period is most appropriate for the program objectives. The DAS allows real-time calculations using meteorological data coupled to pollutant data.

6-4. Meteorological Monitoring and Perimeter Action Levels

a. Introduction. As previously documented, meteorological monitoring can be integrated to the real-time FFMS to provide information on the impact the remediation of the HTRW site is having on the surrounding community. The site-specific PALs are usually established by the regulatory authorities and become part of

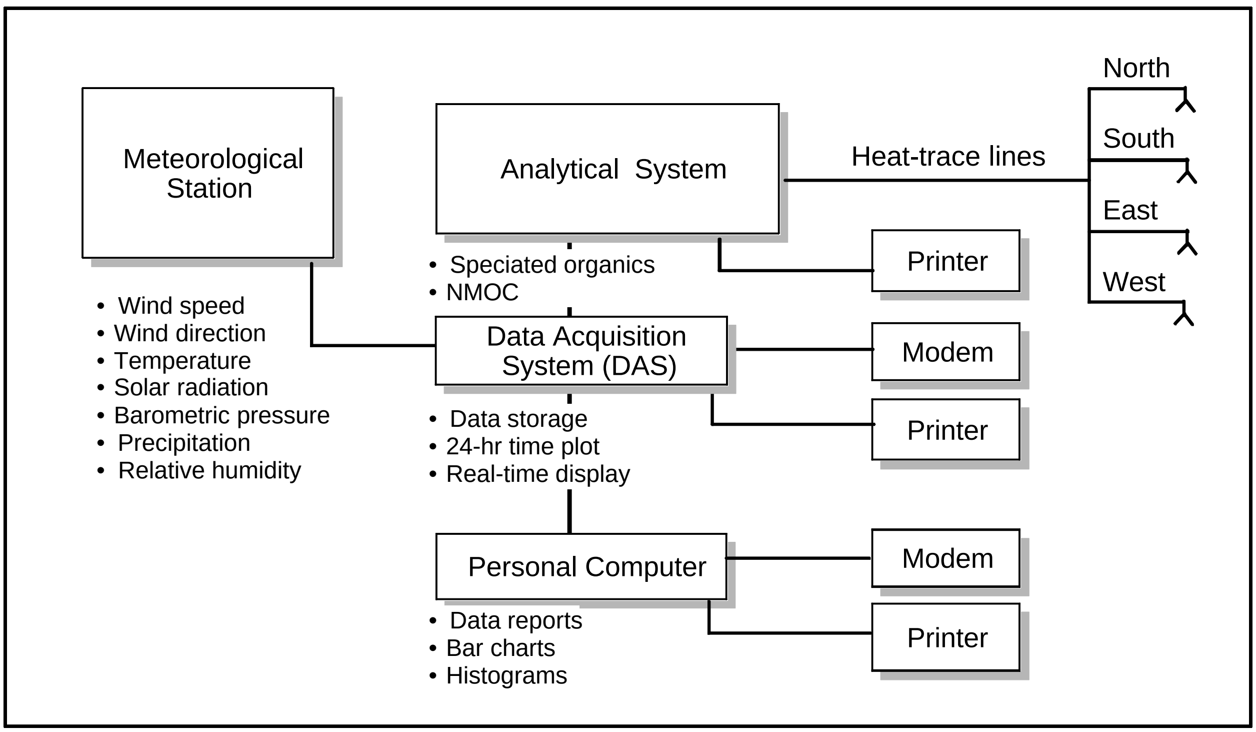

Figure 6-11. Example of connecting the HTRW site meteorological station with the sample collection system and the DAS in the Analytical Center.

the site Health and Safety Plan. The PALs require a progression of alarm levels that may trigger some or all of the following actions:

- Greater specificity in contaminant analysis.
- Correlation of analytical and meteorological data to evaluate source direction.
- Calculation of net downwind concentration.
- Investigation and documentation of probable causes of exceedance.
- Implementation of site management controls, if necessary.

b. Alert levels. Alert levels for all target analytes are preprogrammed within the data acquisition. During any sampling interval, exceedances of either a total NMOC threshold and/or site-specific target analyte thresholds may be determined depending on the specific mode of chromatograph operation. The DAS should cycle through the established sampling schedule, log the individual instrument measurements, and compare the measurements with the preset alert levels. When an exceedance is identified, the DAS should trigger audible alarm mechanisms within the Analytical Center and generate a report as well as initiate further analyses, data storage, and data correlation. A typical HTRW site alarm level operational scheme is described in the following sections.

(1) Alarm level 1 - NMOC exceedance. As described previously, the network of heated sample lines transport sample gas from locations around the HTRW site to the analytical system in the Analytical Center. The microprocessor controlled system allows sequential sampling of each sample line. During routine sampling, the analytical system (i.e., gas chromatograph) is typically operated in the RAM mode for total NMOC. As such, the analytical system extracts a sample gas from each sample line and directs the gas to a detector for gross quantification of NMOC concentration. Resultant data are automatically logged to the DAS. When the total NMOC concentration in a given sample is below the alarm level (i.e., <1 ppm), the manifold apparatus simply proceeds to the next sample line. When total NMOC concentrations exceed the present alert level (i.e., >1 ppm), the microprocessor generates a written report, and a speciated analysis for target analytes in the sample is typically initiated.

(2) Alarm level 2 - Compound Specific Exceedance. In the speciated mode, the sample gas is directed to the analytical system where separation of the total gas sample is performed. Individual contaminants elude from the analytical system (i.e., GC column) and are directed to a detector for quantification. Specific analytes are identified on the basis of chromatograph retention time as compared to regular multi-point calibration of the system. Again, all data are logged to the DAS. If the concentrations of any of the target compounds are below the pre-set alarm level, the microprocessor signals the manifold apparatus to proceed to the next sample line and analytical operation is shifted back to the total NMOC or RAM. If the concentration of any target compound exceeds the pre-set alarm level (2), the microprocessor typically generates a report and initiates a sequence of speciated analyses of sample gas from each of the remaining sample lines. All resultant data are logged in the data storage system. Once a complete circuit of speciated analyses has been completed, the microprocessor signals the manifold apparatus to proceed to the next sample line and shifts analytical operational back to the RAM mode.

(3) Alarm level 3 - Meteorological Data Evaluation and Upwind Compound Specific Exceedance. Subsequent to the speciated analysis for each sample line, the DAS queries the program to determine the location of the upwind sample. If the concentration of any target compound at the upwind location exceeds the pre-set alarm level, the DAS typically generates a report indicating further investigation with a portable organic vapor analyzer in the area of the exceedance is necessary.

To determine the upwind station, the HTRW site is divided into four quadrants, each 90°, as illustrated in Figure 6-12. The four quadrants are defined as:

- Quadrant 1 (Q1): <45°, >315° and <405°, north quadrant.
- Quadrant 2 (Q2): >45° and <135°, >405° and <495°; east quadrant.
- Quadrant 3 (Q3): >135° and <225, >495, south quadrant.
- Quadrant 4 (Q4): >225° and <315°, west quadrant.

To identify which station is the upwind station, time integrated channels in the data logger determine if the wind is in a certain quadrant. If the wind is in a certain quadrant (i.e., the north quadrant), the north time-integrated channel will change its value from 0 to 1. When the wind is no longer in this quadrant, the value will change back. The quadrants are defined by degree ranges that are easily adjustable. There are a total of seven time-integrated channels, one for each direction (North, South, East, West) and three to handle the extra 180° of the wind direction measuring device (range is 0° to 540°). The upwind channels will not activate if the wind speed is less than 1.5 m/s.

(4) Alarm level 4 - Meteorological Data Evaluation and Compound Specific Exceedance (net concentration). If the concentration of all target compounds at the upwind location are below the pre-set alarm level, the microprocessor subtracts the upwind concentrations from those reported for the downwind station to determine the HTRW site net concentration. If the net concentration of any target compound at the downwind location exceeds the pre-set alarm level, the microprocessor generates a report indicating further investigation with a portable organic vapor analyzer in the area of the exceedance, if necessary.

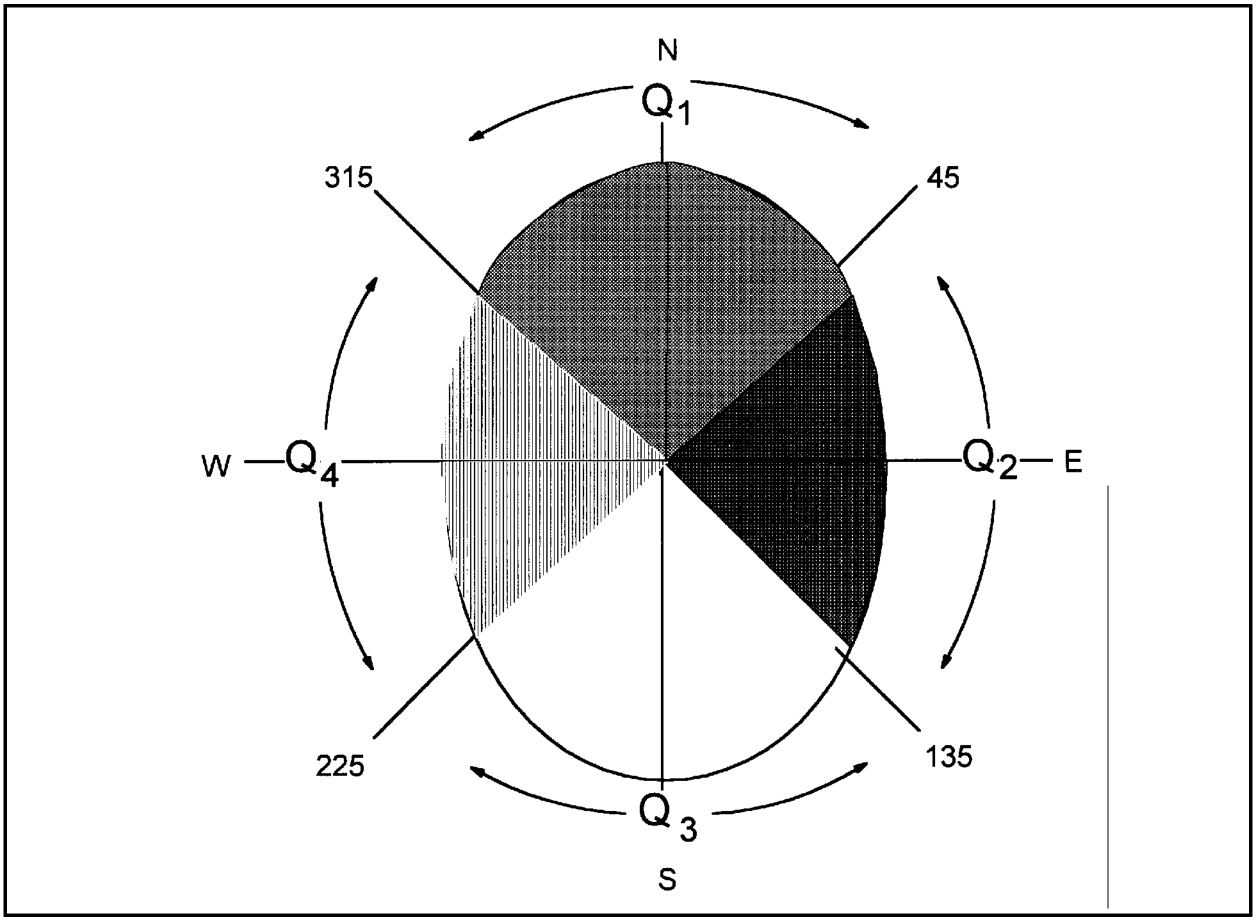

Figure 6-12. Example of HTRW site divided into 90° quadrants for calculating upwind/downwind net concentration of site specific target analytes